

SECTION 933 PRESTRESSING STRAND AND BAR

933-1 Strands for Prestressing.

933-1.1 Carbon Steel Strands for Prestressing: The steel strands for prestressing concrete members shall be Grade 270, low-relaxation seven wire strand and shall conform to the requirements of ASTM A416.

933-1.2 Stainless Steel Strands for Prestressing: The stainless steel strands for prestressing concrete members shall be a high strength stainless steel (HSS) conforming to the chemical requirements of ASTM A276 , UNS S31803 or S32205 (Type 2205) and the mechanical and dimensional requirements of ASTM A416, except the minimum ultimate tensile strength shall be 240 ksi.

933-1.3 Carbon Fiber Reinforced Polymer (CFRP) Strands for Prestressing: Obtain CFRP prestressing strands from producers currently on the Department's Production Facility Listing. Producers seeking inclusion on the list shall meet the requirements of Section 105. CFRP strand shall meet the requirements of ACI 440.4, following the test methods from ACI 440.3. The CFRP strand shall meet the additional requirements of this Section following the sampling frequency and number of specimens required by ACI 440.6.

| Type | <u>Nominal</u> Diameter (in) | <u>Effective</u> <u>Nominal</u> Cross Sectional Area (in ²) | <u>Nominal</u> Ultimate Load (P _u) (kips) | <u>Nominal</u> Ultimate Tensile Stress (ksi) |
|--------------------------|---------------------------------|--|---|---|
| Single Strand - 5.0mm Ø | 0.20 | 0.03 <u>0</u> | 9 | <u>300</u> |
| 7-strand - 7.5mm Ø | 0.30 | 0.05 <u>0</u> | 17 | <u>340</u> |
| 7-strand - 10.5mm Ø | 0.41 | 0.09 <u>0</u> | 32 | <u>356</u> |
| Single Strand - 9.5mm Ø | 0.38 | 0.11 <u>0</u> | 35 | <u>318</u> |
| 7-strand - 12.5mm Ø | 0.49 | 0.12 <u>18</u> | 41 | <u>347</u> |
| Single Strand - 12.7mm Ø | 0.50 | 0.20 <u>196</u> | 59 | <u>301</u> |
| 7-strand - 15.2mm Ø | 0.60 | 0.18 <u>79</u> | 61 | <u>341</u> |
| 19-strand - 20.5mm Ø | 0.81 | 0.32 <u>0</u> | 71 | <u>222</u> |
| 7-strand - 17.2mm Ø | 0.68 | 0.23 <u>4</u> | 79 | <u>338</u> |
| 19-strand - 25.5mm Ø | 1.00 | 0.47 <u>2</u> | 105 | <u>222</u> |
| 19-strand - 28.5mm Ø | 1.12 | 0.62 <u>1</u> | 134 | <u>216</u> |
| 37-strand - 35.5mm Ø | 1.40 | 0.92 <u>16</u> | 189 | <u>206</u> |
| 37-strand - 40.0mm Ø | 1.57 | 1.24 <u>40</u> | 270 | <u>218</u> |

933-2 Steel Bars for Prestressing.

The steel bars for prestressing concrete members shall conform to the requirements of ASTM A722, Type II.

933-3 Steel Parallel Wire Assemblies for Prestressing.

The wire assemblies for prestressing concrete members shall consist of parallel wires of the number and size shown in the Plans and shall conform to the requirements of ASTM A421.

933-4 Anchorages for Prestressing.

933-4.1 For Strands and Bars:

933-4.1.1 Steel Strands and Bars: Meet the requirements of Section 960.

933-4.1.2 Carbon Fiber Reinforced Polymer (CFRP) Strands: Meet the requirements of ACI 440.4R, B.10 – Test method for performance of anchorages of FRP bars.

933-4.2 For Steel Parallel Wire Assemblies: Anchorage for parallel wire assemblies may be provided by Type BA (Button Anchorages) cold-end deformation of the wires bearing against suitable anchorage plates, or by Type WA (Wedge-type Anchorages) without cold end deformations, of the sandwich-plate or conical type. The anchorage device shall be capable of developing at least 90% of the specified ultimate strength of the total number of wires anchored.

Conical type anchorages shall be embedded within the ends of the concrete members unless otherwise specified. Anchorages shall generally bear against embedded grids of reinforcing steel of approved type.

Alternate type anchorages will be considered if proposed by the Contractor. Any alternate anchorage will be required to develop the full specified ultimate strength for bars or at least 90% of the specified ultimate strength for parallel wire assemblies.

933-5 Required Tests for Prestressing Strand and Bar.

933-5.1 General: Tests shall be performed to determine the physical characteristics of prestressing reinforcement. For tests specified to be made by the producer, submit certified test results to the Engineer prior to use.

933-5.2 Strands:

933-5.2.1 Steel Strands: Acceptance of steel prestressing strands shall be based on samples taken by the Department and the producer's certified mill analysis certifying that the test results meet the specification limits of ASTM or AASHTO as specifically designated. Prior to use, submit to the Engineer the producer's certified mill analysis for each heat or production LOT per shipment of strand.

Certifications for steel prestressing strand shall contain, for each heat number or production LOT, all test results required by ASTM A416 and the modulus of elasticity expressed in psi or the stress-strain curve with units identified.

The Engineer will select samples and certified mill analysis representing each shipment at a frequency of one sample per producer, per size of strand, per shipment.

933-5.2.2 Carbon Fiber Reinforced Polymer (CFRP) Strands: ~~Producers of CFRP strand seeking approval to be placed on the Department's Production Facility Listing shall meet the~~ submit to the State Materials Office (SMO), a testing report of the physical and mechanical property requirements of in Table 5-1 for each product. Producers seeking evaluation of a product in accordance with Section 6 must submit test reports conducted by an independent laboratory Qualified testing shall be conducted by an ISO 17025 accreditationed agency using personnel with actual experience running laboratory approved by the Department for performing the FRP test methods for FRP strand. Submit the test reports to the State Materials Office Three production LOTS shall be randomly sampled at the production facility by a designee of the SMO. The minimum number of specimens per production LOT shall be as indicated in Table 5-1. The coefficient of variation (COV) for each test result shall be less than

6%. Outliers shall be subject to further investigation in accordance with ASTM E178. If the COV exceeds 6%, the number of test specimens per production LOT may be doubled a maximum of two times, to meet the COV requirement. Otherwise, the results shall be rejected. A production LOT is defined as a LOT of CFRP strand produced from start to finish with the same constituent materials used in the same proportions without changing any production parameter, such as cure temperature or line speed.

| Property | Test Method | Requirement | Specimens per LOT |
|--|--|--|-------------------|
| Fiber Content Mass Fraction | ASTM D2584 or ASTM D3171 | >55% volume $\geq 70\%$ -weight | <u>10</u> |
| Short-Term Moisture Absorption | ASTM D570, Procedure 7.1; 24 hours immersion at 122°F | $\leq 0.275\%$ (long term immersion to full saturation) | <u>10</u> |
| Long-Term Moisture Absorption | ASTM D570, Procedure 7.4; immersion to full saturation at 122°F | $\leq 1.0\%$ | <u>10</u> |
| Glass Transition Temperature (T_g) | ASTM E1640 -(DMA) or ASTM E1356 -(DSC) | $\geq 230^\circ\text{F}$ $\geq 212^\circ\text{F}$ | <u>3</u> |
| Total Enthalpy of Polymerization (Resin) | ASTM E2160 | Identify the resin system used for each bar size and Report the average value of three replicates for each resin-system used | - |
| Degree of Cure | ASTM E2160 | $\geq 95\%$ of Total polymerization enthalpy | <u>3</u> |
| Measured Cross Sectional Area | ASTM D7205 | Within -5% to +10% of nominal values listed in Table 1-1 | <u>10</u> |
| Ultimate Tensile Strength (UTS) | | \geq Value listed in Table 1-1 | |
| Tensile Modulus | | $\geq 18,000$ ksi | |
| Alkali Resistance with Load | ASTM D7705; set 3 months test duration at $140 \pm 5^\circ\text{F}$. Apply sustained tensile stress to induce tensile strain of 3000 micro-strain; 3 months test duration followed by tensile test per ASTM D7205 | Tensile capacity strength retention $\geq 70\%$ of ultimate tensile stress (UTS) | <u>5</u> |

Table 5-1
Testing Physical and Mechanical Property Requirements for CFRP Qualification of Producers of Prestressing CFRP Strands

| Property | Test Method | Requirement | Specimens per LOT |
|------------------------|--|---|-------------------|
| Creep Rupture Strength | ASTM D7337, 3 months test duration at laboratory conditions. Apply sustained tensile load equivalent to 75% UTS, followed by tensile test per ASTM D7205 | ≥75% Ultimate tensile strength Equivalent sustained load ≥75% UTS AND Tensile strength retention ≥90% UTS | 3 |

933-5.2.2.1 Certification Material Acceptance: ~~Meet the testing requirements of Table 5-2 for product acceptance. The Contractor shall~~ Submit to the Engineer a certification for each production LOT from the producer of the CFRP strand, confirming that the requirements of this Section are met. The certifications shall conform to the requirements of Section 6. ~~Each certification shall cover only one LOT of CFRP strand materials.~~

933-5.2.2.2 Sampling: ~~Test results must meet the requirements of Table 5-2 using an independent ISO 17025 accredited laboratory with actual experience running the test methods for FRP strand. A minimum of six samples of strand representing each LOT or shipment, per manufacturer, and per size of strand will be selected by the Engineer~~ The Engineer will select a minimum total of 42 feet from each production LOT for testing in accordance with Table 5-2. The minimum discrete sample length shall be seven-7 feet. ~~The LOT will be sampled after the entire LOT is delivered to the project site or in an offsite storage facility. Furnish additional strand footage to account for samples selected for testing. CFRP strand shall be available for sampling a minimum of three weeks prior to their installation~~ Testing shall be conducted, at the Contractor's expense, by a Department approved ISO 17025 accredited laboratory. Each test shall be replicated a minimum of three times per production LOT. Submit the test results to the Engineer for review and approval prior to installation.

Table 5-2
Testing requirements for Project Material Acceptance of CFRP Prestressing CFRP Strand

| Property | Test Method | Requirement |
|--------------------------------|--|---------------------------------------|
| Fiber Mass Fraction | ASTM D2584 or ASTM D3171 | ≥70% |
| Short-Term Moisture Absorption | ASTM D570, Procedure 7.1; 24 hours immersion at 122°F | ≤0.25% |
| Glass Transition Temperature | ASTM E1640 (DMA) or ASTM E1356 (DSC) | ≥230°F ≥212°F |
| Degree of Cure | ASTM E2160 | ≥95% of Total polymerization enthalpy |
| Fiber content | ASTM D3171 | Volume fraction ≥55% |
| Void content | ASTM D2734 | ≤1% |
| Moisture absorption | ASTM D570 | ≤0.25% in 24 hours at 122°F |

| Table 5-2 Testing requirements for Project <u>Material</u> Acceptance of <u>CFRP</u> Prestressing CFRP -Strand | | |
|---|-------------------------------------|---|
| Property | Test Method | Requirement |
| Tensile Modulus of elasticity <u>Actual Cross Sectional Area</u> | ASTM D7205 ASTM D7205 | ≥18,000 ksi <u>Within -5% to +10% of nominal values listed in Table 1-1</u> |
| Typical Sizes and Loads <u>Ultimate Tensile Strength</u> | | <u>See ≥ Value listed in Table 1-1</u> |
| <u>Tensile Modulus</u> | | <u>≥18,000 ksi</u> |

933-5.3 Steel Bars: Acceptance of steel prestressing bar shall be based on samples taken by the Department and the producer's certified mill analysis certifying that the test results meet specification limits of the ASTM or AASHTO as specifically designated. Prior to use, submit to the Engineer the producer's certified mill analysis for each heat or production LOT and size per shipment of bars. Certifications of steel prestressing bar shall contain, for each heat number or production LOT, all test results required by ASTM A722 and the modulus of elasticity expressed in psi or the stress-strain curve with units identified.

The Engineer will select samples and certified mill analysis representing each shipment at a frequency of one sample per heat or production LOT, per size of bar, per shipment.

933-5.4 Steel Wires: Acceptance of steel wires shall be based on the producer's certified mill analysis of test results meeting the specification limits of the ASTM or AASHTO as specifically designated. Prior to use, submit to the Engineer the producer's certified mill analysis for each heat or production LOT per shipment of wire. Certifications of steel prestressing wire shall contain, for each heat number or production LOT, all test results required by ASTM A421.